

## Chemistry 11 – Functional Groups Notes

So far we have investigated hydrocarbon alkanes and have found that this particular group has limited uses and properties. If all organic molecules were alkanes, then organic chemistry would be useless and boring!

Luckily, **specific groups of atoms** are found on organic molecules, which give the molecules more **specific properties** and **greater reactivity** with other compounds. These groups of atoms are known as **functional groups**.

- **Functional Group:** a specific group of atoms which exists in a molecule and gives a molecule an ability to react in a specific manner or gives it special properties

Functional groups may allow a molecule to:

- Act as an acid, a base, or both
- React with specific chemicals
- Have a particular solubility
- Have a pleasant or yucky smell
- Become explosive!

So far we have seen a couple of examples of functional groups present on hydrocarbons. They are the **carbon-carbon double bonds**, **carbon-carbon triple bonds**, and **halides**. We will now look at other important functional groups that are present in many everyday organic chemicals.

### General Naming for Hydrocarbons Containing Functional Groups

The following molecules containing functional groups will be named according to these general rules:

1. **Find** the longest carbon chain containing the functional group. This chain determines the parent name of the compound.
2. **Change** the ending of the parent name to the ending specific to the functional group.
3. **Number** the parent chain from the end nearest to the functional group so that the functional group gets the lowest possible number. **Place** this number, along with a dash in front of the parent name.
4. **Identify** the side chains, **determine** the carbon number that they are attached to, and **name** them in alphabetical order.

## Alcohols

- Alcohol: an organic compound containing an “– OH” group
- They have a general formula of  $C_nH_{2n+1}OH$

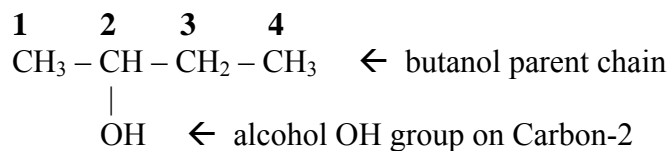
### Properties of Alcohols

- High boiling and melting points (due to **hydrogen bonding** – the H from one OH group interacts with the O from another OH group)
- All alcohols are poisonous, yes...even ethanol!
- They are **polar** solvents (they have a specific positively charged end and a negatively charged end)
- Alcohols have two opposing solubility tendencies due to their structure:
  - ➔ The **polar OH** group tends to **interact** with water (which is also a polar molecule) making the alcohol **soluble**
  - ➔ The **non-polar hydrocarbon chain** tends to make alcohols **insoluble** in water
  - ➔ Therefore, **short-chained** alcohols tend to be more **soluble** in water such as methanol, ethanol, propanol, and butanol, while **longer** chains such as pentanol and higher are **insoluble**.

### Naming Alcohols

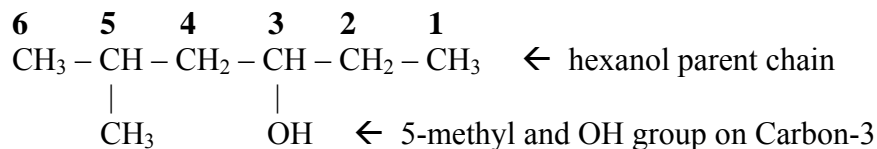
- Use an ending of “**anol**” for the parent chain when naming alcohols

*Example:*



2-butanol

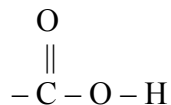
*Example:*



5-methyl-3-hexanol

## Carboxylic Acids

- Carboxylic Acid: an organic compound containing a “– **COOH**” group usually found on the end of a hydrocarbon chain
- The COOH group maybe shown as the following:



- They have a general formula of **C<sub>n</sub>H<sub>2n+1</sub>COOH**

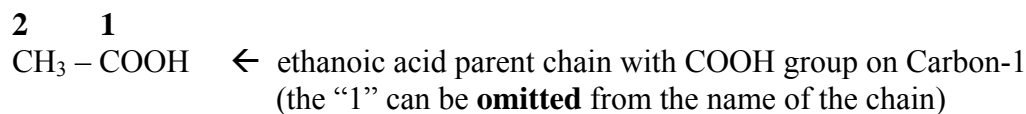
## Properties of Carboxylic Acids

- High boiling and melting points due to hydrogen bonding
- They are polar molecules
- Can act as **acids** (usually referred to as organic acids)

## Naming Carboxylic Acids

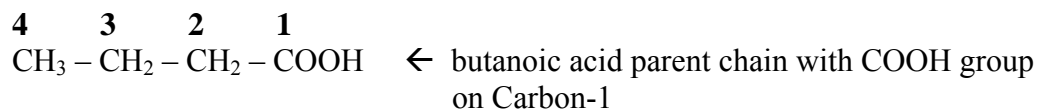
- Use an ending of “**anoic acid**” for the parent chain when naming carboxylic acids  
(**Note: the carbon in the COOH group is included in the parent chain!**)

*Example:*



Ethanoic Acid (commonly called Acetic Acid – found in vinegar!)

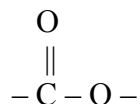
*Example:*



Butanoic Acid (the smell from smelly feet!)

## Esters

- Ester: an organic compound which a “– COO –” group joins two hydrocarbon chains
- The COO group maybe shown as the following:



- They have a general formula of  $\text{C}_n\text{H}_{2n+2}\text{COO}$

### Properties of Esters

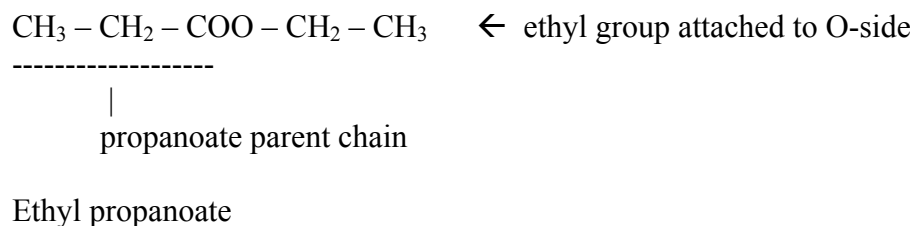
- They are good solvents (eg. Used in nail polish remover)
- Used to make polymers (long-chained molecules); found in fats, oils, and waxes
- Pleasant smelling; often used in foods and other fragrances

| Ester            | Odour      | Ester             | Odour       |
|------------------|------------|-------------------|-------------|
| Ethyl butanoate  | Pineapples | Pentyl propanoate | Apricots    |
| Pentyl ethanoate | Bananas    | Ethyl methanoate  | Raspberries |
| Octyl ethanoate  | Oranges    | Methyl butanoate  | Apples      |

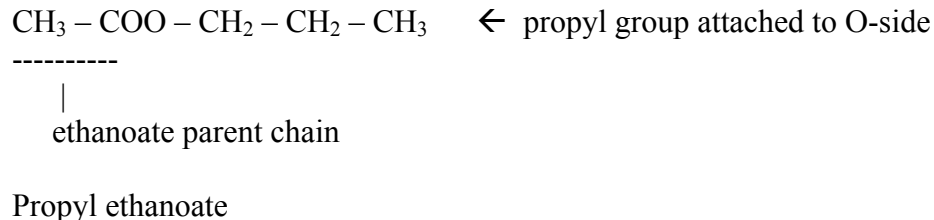
### Naming Esters (Note the following exceptions:)

- Use an ending of “**anoate**” for the parent chain when naming esters (**Note: You can omit the position of the COO group in the naming of the parent chain**)
- The hydrocarbon chain attached to the **carbon side** of the COO group is called the **parent chain**. The carbon in the COO group is also part of the parent chain!
- The hydrocarbon chain attached to the **oxygen side** of the COO group is named as an **alkyl group**. The name of this alkyl group exists as a **separate word** from the parent chain.

*Example:*

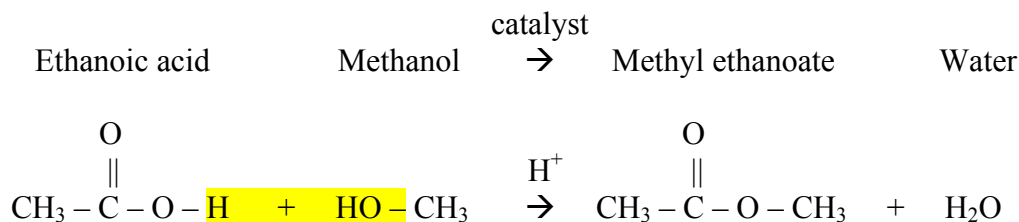


*Example:*



## Preparations of Esters

- Esters are made by reacting a **carboxylic acid** with an **alcohol** in the presence of an **acid catalyst** such as HCl or H<sub>2</sub>SO<sub>4</sub>. This process is known as an **esterification** reaction.
- The following is an example of preparing methyl ethanoate from ethanoic acid and methanol:



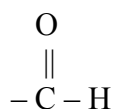
The H from the acid and the OH from the alcohol are removed to form H<sub>2</sub>O.

Ethanoic acid loses an H to become “ethanoate” in the ester. Methanol loses OH, to become a “methyl” group in the ester.

*Try to name the products and draw the esterification reaction for each test tube in Lab 23B.*

## Aldehydes

- Aldehyde: an organic compound which has a “– CHO” group at the end of a hydrocarbon chain
- The CHO group maybe shown as the following:



- They have a general formula of **C<sub>n</sub>H<sub>2n</sub>O**

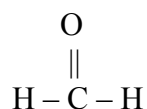
## Properties of Aldehydes

- Generally soluble in water due to hydrogen bonding
- Common aldehydes are liquids
- Distinctive odours (generally pleasant!)

## Naming Aldehydes

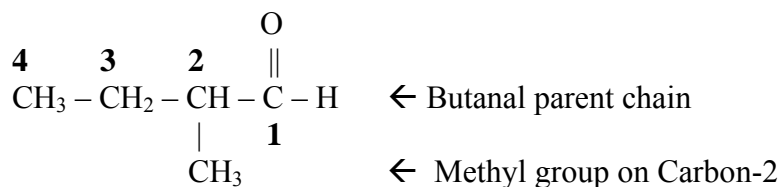
- Use an ending of “**anal**” for the parent chain when naming aldehydes (**Note: the carbon in the CHO group is included in the parent chain!**)
- Since the CHO group is found on the **end** of a hydrocarbon chain, the **position** of the CHO group can be **omitted** from the parent chain name.

*Example:*



Methanal (commonly called Formaldehyde – Used as a preservative in biological specimens)

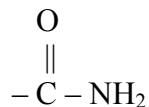
*Example:*



2-methylbutanal

## Amides

- Amide: an organic compound which has a “– CONH<sub>2</sub>” group usually at the end of a hydrocarbon chain
- The CONH<sub>2</sub> group maybe shown as the following:



- They have a general formula of C<sub>n</sub>H<sub>2n+1</sub>CONH<sub>2</sub>

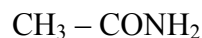
## Properties of Amides

- Polar molecules and good solvents
- The amide group forms the backbone of all protein molecules (links individual amino acid subunits together)
- Can be used to form synthetic polymers

## Naming Amides

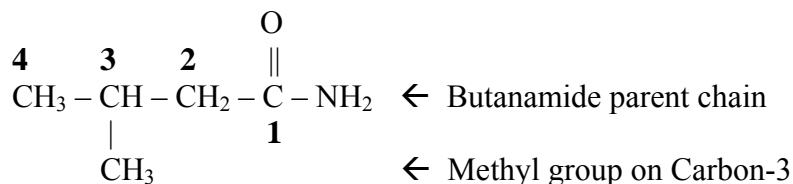
- Use an ending of “**anamide**” for the parent chain when naming amides (**Note: the carbon in the CONH<sub>2</sub> group is included in the parent chain!**)
- Since the CONH<sub>2</sub> group is found on the **end** of a hydrocarbon chain, the **position** of the CONH<sub>2</sub> group can be **omitted** from the parent chain name.

*Example:*



Ethanamide

*Example:*



3-methylbutanamide

## Ketones

- Ketone: an organic compound which has a “– CO –” group in the hydrocarbon chain (not at the ends!)
- The CO group maybe shown as the following:



- They have a general formula of  $\text{C}_n\text{H}_{2n}\text{O}$  (same as aldehydes)

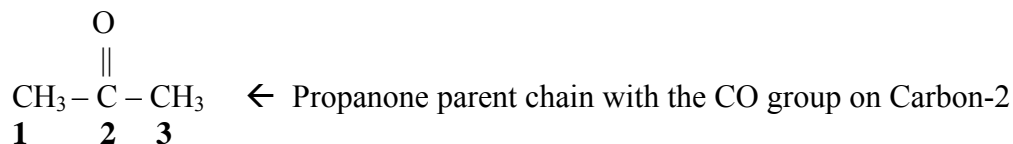
## Properties of Ketones

- Similar properties as Aldehydes

## Naming Ketones

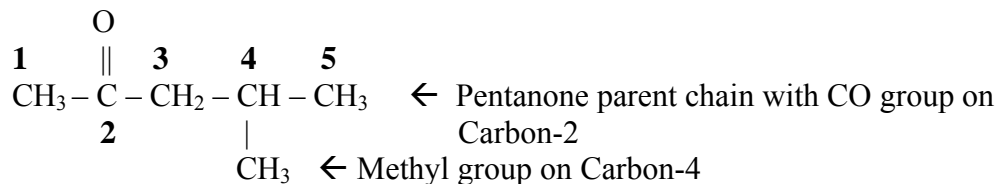
- Use an ending of “**anone**” for the parent chain when naming ketones (**Note: the carbon in the CO group is included in the parent chain!**)

*Example:*



2-propanone (known as Acetone – common ingredient in nail polish remover)

*Example:*



4-methyl-2-pentanone



## Amines

- Amine: an organic compound containing a “–NH<sub>2</sub>” group
- They have a general formula of C<sub>n</sub>H<sub>2n+1</sub>NH<sub>2</sub>

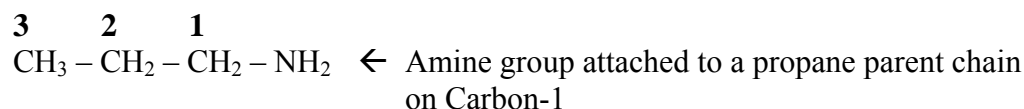
### Properties of Amines

- They are **organic bases** and react with acids
- Smelly compounds (tend to have a fish-like odour)

### Naming Amines

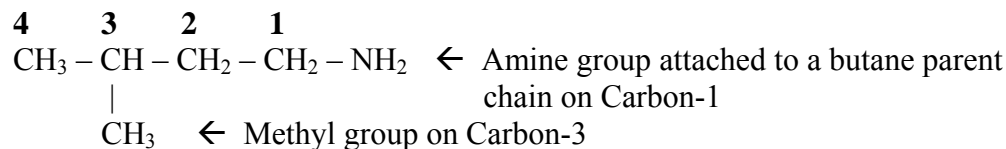
- Use an ending of “**anamine**” for the parent chain when naming amines

*Example:*



1-propanamine

*Example:*



3-methyl-1-butanamine

## Ethers

- Ether: an organic compound in which an **oxygen** joins two hydrocarbon groups together
- The oxygen atom maybe shown as the following:



- They have a general formula of C<sub>n</sub>H<sub>2n+2</sub>O

## Properties of Ethers

- Tend to be quite **unreactive** molecules
- Good solvents
- Some ethers (eg. Diethyl ether) are used as an **anaesthetic** in hospitals on people and by biologists on animals and insects

## Naming Ethers (Note the following exceptions:)

- Consider the **oxygen** atom in the ether group to be the **parent chain** and use the name “**ether**”
- Treat the **two** hydrocarbon chains attached to the oxygen atom as **alkyl side chains** and name them in alphabetical order with **spaces** in between each side chain.

*Example:*

$\text{CH}_3 - \text{O} - \text{CH}_2 - \text{CH}_3$      $\leftarrow$  Methyl and ethyl side chains attached to the oxygen

Ethyl methyl ether

*Example:*

$\text{CH}_3 - \text{O} - \text{CH}_3$      $\leftarrow$  Two methyl groups attached to oxygen

Dimethyl ether

In Organic Chemistry, you will come across molecules that contain **more than one type** of functional groups. In that case, you will have to **determine** which functional group has the **highest priority** in naming by using a functional groups **naming chart**. You will not be expected to do this in Chemistry 11 but for future reference, the following chart is provided.

## Chemistry 11 – Functional Groups Naming Chart

Highest  
Priority

|   | Functional Group       | Formula  | General Equation                         | Example  | Nomenclature                                    |
|---|------------------------|--|--|--|---|
| ↑ | Carboxylic Acid        | $\begin{array}{c} \text{O} \\    \\ -\text{C}-\text{OH} \end{array}$   | $\text{C}_n\text{H}_{2n+1}\text{COOH}$   | $\begin{array}{c} \text{O} \\    \\ \text{CH}_3-\text{CH}_2-\text{C}-\text{OH} \\ \text{Propanoic acid} \end{array}$               | <b>- anoic acid</b><br>(pos. # not reqd!)       |
|   | Ester                  | $\begin{array}{c} \text{O} \\    \\ -\text{C}-\text{O}- \end{array}$   | $\text{C}_n\text{H}_{2n+2}\text{COO}$    | $\begin{array}{c} \text{O} \\    \\ \text{CH}_3-\text{CH}_2-\text{C}-\text{O}-\text{CH}_3 \\ \text{Methyl propanoate} \end{array}$ | <b>- anoate</b><br>(alkyl group on oxygen atom) |
|   | Amide                  | $\begin{array}{c} \text{O} \\    \\ -\text{C}-\text{NH}_2 \end{array}$ | $\text{C}_n\text{H}_{2n+1}\text{CONH}_2$ | $\begin{array}{c} \text{O} \\    \\ \text{CH}_3-\text{CH}_2-\text{C}-\text{NH}_2 \\ \text{Propanamide} \end{array}$                | <b>- anamide</b><br>(pos. # not reqd!)          |
|   | Aldehyde               | $\begin{array}{c} \text{O} \\    \\ -\text{C}-\text{H} \end{array}$    | $\text{C}_n\text{H}_{2n}\text{O}$        | $\begin{array}{c} \text{O} \\    \\ \text{CH}_3-\text{CH}_2-\text{C}-\text{H} \\ \text{Propanal} \end{array}$                      | <b>- anal</b><br>(pos. # not reqd!)             |
|   | Ketone                 | $\begin{array}{c} \text{O} \\    \\ -\text{C}- \end{array}$            | $\text{C}_n\text{H}_{2n}\text{O}$        | $\begin{array}{c} \text{O} \\    \\ \text{CH}_3-\text{CH}_2-\text{C}-\text{CH}_2-\text{CH}_3 \\ \text{3-pentanone} \end{array}$    | <b>- anone</b>                                  |
|   | Alcohol                | $-\text{OH}$   | $\text{C}_n\text{H}_{2n+1}\text{OH}$     | $\text{CH}_3-\text{CH}_2-\text{CH}_2-\text{OH}$<br>1-propanol  | <b>- anol</b>                                   |
|   | Amine                  | $-\text{NH}_2$   | $\text{C}_n\text{H}_{2n+1}\text{NH}_2$   | $\text{CH}_3-\text{CH}_2-\text{CH}_2-\text{NH}_2$<br>1-propanamine   | <b>- anamine</b>                                |
|   | Ether                  | $-\text{O}-$   | $\text{C}_n\text{H}_{2n+2}\text{O}$      | $\text{CH}_3-\text{O}-\text{CH}_2-\text{CH}_3$<br>Ethyl methyl ether   | <b>- ether</b><br>(alkyl alkyl ether)           |
|   | Alkene                 | $\text{C}=\text{C}$  | $\text{C}_n\text{H}_{2n}$                | $\text{CH}_2=\text{CH}-\text{CH}_2-\text{CH}_3$<br>1-butene  | <b>- ene</b><br>[cis/trans isomers]             |
|   | Alkyne                 | $\text{C}\equiv\text{C}$   | $\text{C}_n\text{H}_{2n-2}$              | $\text{CH}\equiv\text{C}-\text{CH}_2-\text{CH}_3$<br>1-butyne  | <b>- yne</b>                                    |
|   | Alkane & Alkyl Halides | $\text{C}-\text{C}$<br>F, Cl, Br, I                                    | $\text{C}_n\text{H}_{2n+2}$              | $\text{CH}_3-\text{CH}_2-\text{CH}_2-\text{Cl}$<br>1-chloropropane   | <b>- ane</b>                                    |

Lowest  
Priority